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Risk Analysis and Timber Investments: A Bibliography of Theory and Applications

Carol A. Hyldahl and David C. Baumgartner

North Central Forest Experiment Station
Forest Service—U.S. Department of Agriculture
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St. Paul, Minnesota 55108
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During the 1980's, standard financial analysis methods, particularly portfolio theory and asset pricing models, were increasingly used to quantify the risk and return of investments in forest land and timber. Although these methods may be difficult to directly apply to forestry investment situations, they have great potential for clarifying the risk aspects of a wide range of forestry decisions. As newcomers to the analysis of risk in forestry, we spent many hours locating and assembling studies of risk in forestry investments and their theoretical underpinnings in the voluminous financial literature. By assembling a core of materials we found most useful, we hope to encourage the further use and refinement of these approaches to the quantification of risk in forestry.

This bibliography includes most of the small, but rapidly growing, amount of recent material directly related to risk in forestry in the United States up to 1989. At this point it relates primarily to financial rather than biophysical risks. Only representative references are provided from the huge literature of general financial theory, including those on portfolio theory, asset pricing models, risk return analysis, options pricing, and decision theory.

We sent the draft of this bibliography to several researchers and institutional investors currently involved with quantifying the risk aspect of forestry investments. We invited them to review the draft and to suggest changes and additional publications that should be considered. We would like to acknowledge the encouragement and many contributions of Mr. James F. Webb, Vice President for Timberland Investments of the First Wachovia Bank and Trust, Winston-Salem, North Carolina; Dr. Clark Binkley, Dean, Faculty of Forestry, University of British Columbia; Dr. Courtland Washburn of the Hancock Timber Resource Group, Boston, Massachusetts; and Dr. F. Christian Zinkhan, Chairman, Lundy-Fetterman School of Business, Campbell University. We would also like to acknowledge Noel J. Bennett, Project Secretary, for carefully typing many drafts of this bibliography.

This document contains 110 annotated references and 17 additional textbook references. We plan to continue to collect material and keep the bibliography current. Readers are invited to send materials to the authors.

Carol Hyldahl is an Economist and **David Baumgartner** is a Principal Research Forest Economist with the North Central Forest Experiment Station, East Lansing, Michigan.

Capital Asset Pricing Model

1. Barry, Peter J. 1980. **Capital asset pricing and farm real estate**. American Journal of Agricultural Economics. 62(3): 549-553.

   Uses the capital asset pricing model (CAPM) to estimate risk premiums for holding farm real estate in a well-diversified market portfolio. Estimates risk premiums for farm real estate at the national level and for farm production regions of the United States. Evaluates the CAPM results in light of farm real estate's unique characteristics.

   KEY WORDS: market portfolio, risk premiums

2. Binkley, Clark S.; Washburn, Courtland L. 1988a. **The diversification potential of forestry investments: some comments with examples from the U.S. South**. In: Economic evaluation of timberland investments; Working Papers, 2d ed. 1989 June 1; New Haven, CT: Yale University, School of Forestry and Environmental Studies. 26 p.

Discusses three limitations currently seen in research on the diversification potential of forestry investments: (1) returns to ownership of land, (2) timber versus stumpage prices, and (3) geographic variation in financial risk. Illustrates these points with empirical Southern pine management data from the U.S. South. Finds that the appropriate discount rate for purchase decisions is less than the discount rate appropriate for forest management decisions. States the true risk, as measured by the CAPM and using stumpage prices, is much higher than what would be inferred using lumber prices. Suggests care must be taken when examining the risk-return relationships that exist in a particular locality. States it may be advantageous, in terms of reducing financial risk, to hold a geographically diversified portfolio of forest investments.

KEY WORDS: discount rate, Southern pine, financial risk, stumpage prices

3. Binkley, Clark S.; Washburn, Courtland L. 1988b. **The financial risk of private timberlands investments in South Carolina**. In: Potter, Richard H., ed. Proceedings of the 1989 Southern forest economics workshop: Restructuring to cope with changing times; 1989 March 1-3; San Antonio, TX. SCFER Work. Pap. 69. Research Triangle Park, NC: Southeastern Center for Forest Economics Research. 37 p.

Calculates risk-return relationships for private timberland investments in South Carolina using the capital asset pricing model (CAPM). Presents results for three different site classes (for the State as a whole and for three market regions within South Carolina) and for three different product classifications. States it is appropriate to use a low risk-adjusted discount rate because the risk with timberland investments is only slightly above the rate on U.S. Treasury bills.

KEY WORDS: low risk-adjusted discount rate, site classes

4. Black, Fischer; Jensen, Michael C.; Scholes, Myron. 1972. **The capital asset pricing model: some empirical tests**. In: Jensen, M.C., ed. Studies in the theory of capital markets. New York: Praeger Publishers: 79-121.

Presents additional tests of the capital asset pricing model that avoid some of the problems of earlier studies and that provide additional insights into the nature of the structure of security returns. Shows that the use of cross-sectional tests of significance can be misleading and therefore do not provide direct tests of validity of the relationship between expected return and its "systematic risk." Provides a more powerful time series test of the validity of the model. Gives results that the expected excess returns on high-beta assets are lower than the model suggests and that the expected excess returns on low-beta assets are higher than the model suggests. Also finds evidence to support the expected excess return on an asset is not strictly proportional to its beta. Provides a solution to measurement error bias from cross-sectional tests. Finds that the mean of the beta factor has had a positive trend during the period 1931-1965. Suggests that the evidence is sufficiently strong to warrant rejecting the original capital asset pricing model.

KEY WORDS: cross-sectional tests of significance, beta factor

5. Chambers, Robert G. 1989. **Financial asset pricing models and their use in managing timberland portfolios**. In: Potter, Richard H., ed. Proceedings of the 1989 Southern forest economics workshop: Restructuring to cope with changing times; 1989 March 1-3; San Antonio, TX. SCFER Work. Pap. 69. Research Triangle Park, NC: Southeastern Center for Forest Economics Research: 66-77.

Agrees that no feasible methodology has been developed for determining a separate CAPM for timberland. Gives the following four applications in the event a suitable index is developed: allocating assets, determining discount rate for timberland investments, evaluating timberland manager's performance, and constructing an efficient timberland portfolio. Uses a detailed example to explain the construction of an efficient timberland portfolio.

KEY WORDS: timberland index

6. Cubbage, Frederick W.; Harris, Thomas G., Jr.; Redmond, Clair H. 1988. **Measuring risk and returns of timber investments using the capital asset pricing model**. Res. Pap. 562. Athens, GA: University of Georgia Agricultural Experiment Station. 31 p.

Applies modern financial analysis techniques of evaluating an asset's risk and return to timber investments based on historical stumpage price series collected for various regions of the United States from about 1952 to 1986. Calculates average returns and variations on a periodic basis. Using CAPM, regresses changes in timber prices, adjusted for the risk-free interest rate, against changes to a similarly adjusted market index of stock prices. Shows that timber price beta values often were negative, indicating a slight inverse relationship to the market performance of stock and hence a reduction in risk for an investor's total assets portfolio. Finds that timber price alphas tended to be positive, suggesting a superior return for the amount of market risk exposure.

KEY WORDS: timber investment

7. DeForest, Christopher E.; Redmond, Clair H.; Cubbage, Frederick W.; Harris, Thomas G., Jr. 1989. **The contribution of timber assets to the returns and variability of a mixed portfolio**. In: Potter, Richard H., ed. Proceedings of the 1989 Southern forest economics workshop: Restructuring to cope with changing times; 1989 March 1-3; San Antonio, TX. SCFER Work. Pap. 69. Research Triangle Park, NC: Southeastern Center for Forest Economics Research: 27-44.

Finds that using stumpage price betas from prior CAPM work and incorporating timber assets in a market portfolio reduce the variability of its returns. Shows that the size of the timber component determined the magnitude of the reduction. States that different stumpage betas (-1.5 to 1.5) had little effect on portfolio variability when timber was 5 percent of the portfolio; greater effects occurred at 50 percent. Finds that raising annual stumpage return variability (1.0 to 1.5) produced similar results on portfolio variability. Observes that neither changing betas nor increased stumpage variability altered total portfolio returns.

KEY WORDS: stumpage, investment

8. Elton, Edwin J.; Gruber, Martin J.; Urich, Thomas J. 1978. **Are betas best?** Journal of Finance. 33(5): 1375-1384.

Reviews four studies on the plausibility of the original or modified capital asset pricing model. Presents two new approaches to either explain the apparent deficiencies in the original model on measurement and other statistical grounds or to modify that model to bring theory in closer conformance with reality. In the first approach substitutes *ex ante* (expected) for *ex post* (realized) measures of return in capital asset pricing theory. In the second approach uses data on bond indexes and a large sample of individual bonds both to obtain improved measures of the rate of return on the portfolio of marketable risky assets and to incorporate returns on individual bonds as well as on individual stocks in the return-risk relationships used to test capital asset pricing theory.

KEY WORDS: bond indexes, *ex ante* measures of return, *ex post* measures of return

9. Friend, Irwin; Westerfield, Randolph; Granito, Michael. 1978. **New evidence on the capital asset pricing model**. Journal of Finance. 33(3): 903-920.

Conducts two new tests of the capital asset pricing model. Substitutes *ex ante* (expected) for *ex post* (realized) measures of return in testing capital asset pricing theory. Also uses data on bond indexes and a large sample of individual bonds both to obtain improved measures of the rate of return on the portfolio of marketable risky assets and to incorporate returns on individual bonds as well as on individual stock in the return-risk relationships used to test capital asset pricing theory. Finds that the residual standard deviation of return and related variance measures plays as significant a role in the pricing of risky assets as the beta coefficient. Indicates the risk-return relations for bonds may be significantly different than those for stocks, suggesting at least some degree of segmentation in the factors affecting the two markets.

KEY WORDS: risk-return, bond market, stocks

10. Holthausen, Duncan M.; Hughes, John S. 1978. **Commodity returns and capital assets pricing**. Financial Management. 7(2): 37-44.

Looks at commodity return characteristics to see if they are serious enough to compromise the capital asset pricing model (CAPM). Offers evidence on the descriptive validity of certain assumptions upon which CAPM is usually predicated and on the return generating process that the model implies. Finds that their results do not support the model. Feels results imply that financial managers may find it desirable to include commodities in a portfolio of risky assets because returns have not been fully adjusted for diversifiable risk.

KEY WORDS: commodity returns

11. Jensen, Michael. 1969. **Risk, the pricing of capital assets and the evaluation of investment portfolios**. Journal of Business. 42(2): 167-247.

Develops a model for evaluating the performance of portfolios of risky assets under the assumption of homogeneous investor horizon periods. Reviews (1) a theory of rational choice under uncertainty; (2) the normative theory of portfolio selection; and (3) a closely associated theoretical model of capital assets pricing under uncertainty. Defines the "market model" and the concept of "systematic risk" and discusses their application to the evaluation problem. Derives measures of portfolio "performance" under alternative assumptions regarding the existence of finite or infinite variances for the distributions of returns. Discusses the "horizon problem," a solution to it, and the extension of the evaluation model to a world in which investors have heterogeneous horizon periods. Derives a measure of "efficiency" and examines the relationship between the concepts of "performance" and "efficiency." Discusses the concept of "systematic risk" for 115 mutual funds and the assumptions of the "market model" and includes the results of an application of the model to the evaluation of these 115 mutual fund portfolios.

KEY WORDS: uncertainty, efficiency

12. Lintner, John. 1965. **The valuation risk assets and the selection of risky investments in stock portfolios and capital budgets**. Review of Economic Statistics. 47(1): 13-37.

Discusses the problem of selecting optimal security portfolios by risk-averse investors who have the alternative of investing in risk-free securities with a positive return and who can sell short if they wish. Develops various significant equilibrium properties within the risk asset portfolio. Derives a set of (stable) equilibrium market prices that explicitly reflect the presence of uncertainty *per se* (as distinct from the effects of diverse expectations) and derives further implications of such uncertainty. Considers some of the implications of these results for the normative aspects of the capital budgeting decisions of a company whose stock is traded in the market. Examines the complications introduced by institutional units on amounts that either individuals or corporations may borrow at given rates by rising costs of borrowed funds and certain other "real world" complications.

KEY WORDS: risk, uncertainty, portfolio, capital budgeting

13. Mossin, Jan. 1966. **Equilibrium in a capital asset market**. Econometrica. 34(4): 768-783.

Investigates the properties of a market for risky assets on the basis of a simple model of general equilibrium of exchange where individual investors seek to maximize preference functions over expected yield and variance of yield on their portfolios. Outlines a theory of market risk premiums. Shows that general equilibrium implies the existence of a so-called "market line," relating per dollar expected yield and standard deviation of yield. Discusses the concept of price of risk in terms of the slope of this line.

KEY WORDS: general equilibrium model, market risk premiums, pure risk

14. Olsen, Robert A.; Terpstra, Robert H. 1981. **An application of capital asset pricing to the spot market for softwood logs in Oregon**. Forest Science. 27(2): 215-223.

Uses the capital asset pricing model to analyze risk, return, and competition in a major spot log market in Oregon from 1968 to 1978. Calculates holding period returns on 13 individual log species and grades using actual log sale prices and storage costs. Finds that generally the market is competitive and that log investors earn a return that approximates the yield on U.S. Treasury bills. Also finds that log returns do not appear to exhibit any significant amount of systematic or "market related" risk.

KEY WORDS: risk analysis, return analysis, spot log market

15. Redmond, Clair H.; Cubbage, Frederick W. 1988. **Portfolio risk and returns from timber asset investments**. Land Economics. 64(4): 325-337.

Investigates the application of modern portfolio theory and the capital asset pricing model (CAPM) in evaluating timber assets and the application of the model to many timber price series. Finds that the problems with the composition of the true market portfolio, the low explanatory power of the model, and the low accuracy of prediction were exhibited in the timber price analyses, just as they are in the financial literature. States that the results must be interpreted with equal caution for both financial assets and timberland investments. Proves that the timber price series was statistically better suited for CAPM than researchers found in applications to other commodities. Discusses the desirability of including timber in a portfolio because all sawtimber markets had negative betas.

KEY WORDS: timberland investment, modern portfolio theory, risk

16. Sharpe, William F. 1964. **Capital asset prices: a theory of market equilibrium under conditions of risk**. Journal of Finance. 19(3): 425-442.

Looks at a market equilibrium theory of asset prices under conditions of risk. Shows that this extension of the investor behavior model provides a theory whose implications are consistent with the assertions of traditional financial theory. Sheds light on the relationship between the price of an asset and the various components of its overall risk.

KEY WORDS: market equilibrium theory, investor behavior model

17. Sharpe, William F. 1984. **Factor models, CAPMs, and the ABT**. Journal of Portfolio Management. 11(1): 21-25.

Describes the factor models, CAPM's, and the arbitrage pricing theory. Considers a synthesis of the three models. States that although the importance of various factors and the preferences of investors change, we need not abandon a valuable framework within which we can methodically approach investment decisions. Thinks that a useful set of tools has been developed and should continue to be developed as long as we use these tools intelligently, cautiously, and humbly.

KEY WORDS: portfolio, risk-return

18. Vasicek, Oldrich A. 1973. **A note on using cross-sectional information in Bayesian estimation of security betas**. Journal of Finance. 8(5): 1233-1239.

Presents a method for generating Bayesian estimates comparing the regression coefficients of return rates between a security and a market index. Gives explicit formulas for the estimates. Discusses the comparison of the Bayesian approach with the current practice of sampling-theory procedures.

KEY WORDS: sampling theory, Bayesian estimates, regression coefficients

Modern Portfolio Theory

19. Blume, Marshall. 1971. **On the assessment of risk**. Journal of Finance. 26(1): 1-10.

Examines the statistical properties of the coefficient of nondiversifiable risk or, more simply, the beta coefficient in the market model. Defines this beta coefficient and presents a brief nonrigorous justification of its use as a measure of risk. Discusses the sample and its basic properties. Examines the stationarity beta coefficient and proposes a method for obtaining improved assessments of this measure of risk.

KEY WORDS: coefficient of nondiversifiable risk, beta coefficient

20. Cohen, Kalmen J.; Pogue, Jerry A. 1968. **An empirical evaluation of alternative portfolio selection models**. Journal of Business. 40(2): 166-193.

Evaluates the *ex ante* and *ex post* performances of a number of single-period portfolio selection models based on the Markowitz formulation but representing successive steps toward simpler models that pose fewer problems in data preparing and computing. States these simpler models represent the covariance relationships between individual securities and one or more

indexes of industry or market performance. Finds that the *ex post* performance of the index models is not dominated by the Markowitz formulation. Also finds that, for strictly common stock universes, the performance of the multi-index models is not superior to that of the single-index formulation, indicating the secondary importance of industry considerations for common stock portfolios. Compares the *ex post* performance of the efficient sets to that of randomly selected portfolios and actual performance of 78 common stock mutual funds. Finds that, even with a naive security evaluation model, the efficient sets dominate the random portfolios and are not dominated by the mutual funds.

KEY WORDS: single-index models, multi-index models

21. Collins, Robert A.; Barry, Peter J. 1986. **Risk analysis with single-index portfolio models: an application to farm planning**. American Journal of Agricultural Economics. 68(1): 152-161.

Adapts the single-index portfolio model, and the separation theorem, to develop an approximation solution method to the farm crop diversification problem. Attempts to develop a risk measure that is solvable with microcomputers or modern handheld calculators. Intends to produce a normative model with possible farm extension applications.

KEY WORDS: risk methods, hand calculators, single-index model

22. Elton, Edwin J.; Gruber, Martin J.; Padberg, Manford W. 1976. **Simple criteria for optimal portfolio selection**. Journal of Finance. 31(5): 1341-1357.

Identifies three problems that keep portfolio theory from being implemented: (1) difficulty in estimating the type of input data necessary, (2) time and cost necessary to generate efficient portfolios, and (3) difficulty of educating portfolio managers to relate to risk-return trade offs expressed in terms of covariance as well as returns and standard deviations. Employs two approaches formulated to solve the first problem in a manner that should eliminate the second and third problems. The two approaches are: (1) to use a single-index model to generate a variance-covariance matrix, and (2) to assume a simple structure for the variance-covariance matrix.

KEY WORDS: modern portfolio theory, single-index models, variance-covariance matrix

23. Farrell, James L., Jr. 1974. **Analyzing covariation of returns to determine homogeneous stock groupings**. Journal of Business. 47(2): 186-207.

Employs several statistical techniques for testing the hypothesis that classification according to (1) growth, (2) stable, and (3) cyclical characteristics represents a factor for grouping stocks. Finds that it was appropriate to assign a factor for explaining a common stock's variance of returns in addition to market, industry, and company, and based upon a system of classification corresponding to (1) growth, (2) stable, (3) cyclical, and (4) oil stocks. Finds that the four-index model provides a closer approximation to the true correlation matrix than was provided by the single-index model. Indicates that the risk and return measures developed in conjunction with the test of the form of the regression equation and a statistical test of these measures are consistent as well as independent of risk-return relationships among the four groups of stock.

KEY WORDS: multi-index model, single-index model, risk-return

24. Grauer, Robert R.; Hakansson, Nils H. 1986. **A half century of returns on levered and unlevered portfolios of stocks, bonds, and bills, with and without small stocks**. Journal of Business. 59(2): 287-318.

Applies the multiperiod portfolio theory to construct and rebalance portfolios composed of U.S. stocks, corporate bonds, government bonds, and a risk-free asset, with small stocks included as a separate investment vehicle. Bases probability assessments on the past, joint empirical distribution. Finds (1) small stocks, while totally ignored at times, entered even the most risk-averse portfolios most of the time; and (2) small stocks, when chosen, tended to replace common stocks (except in the 1970's and early 1980's when they were primarily held in lieu of the risk-free asset).

KEY WORDS: multiperiod portfolio theory

25. Malkiel, Burton G. 1989. **Is the stock market efficient?** Science. 243(4896): 1313-1318.

Defines and analyzes the efficient market hypothesis and the three levels of market efficiency: (1) the weak form, (2) the semi-strong form, and (3) the strong form. Discusses the theory of stock valuation and the market crash of October 1987. States that pricing irregularities may exist and even persist for periods of time, and markets can be influenced by fads and fashions; however, any excesses in market valuations will be corrected. Suspects that with the passage of time and the increasing sophistication of data bases and empirical techniques, the profession will not abandon its belief that the stock market is remarkably efficient in its use of information.

KEY WORDS: efficient market hypotheses, stock valuation, October 1987 market crash

26. Markowitz, Harry. 1952. **Portfolio selection**. Journal of Finance. 7(March): [77-91].

Pioneers modern portfolio theory with this article. Considers the second stage in the process of selecting a portfolio; this stage begins with the relevant beliefs about the securities involved and ends with a selection of a portfolio. Considers the rule that the investor does (or should) maximize discounted expected, or anticipated, returns. Rejects this rule both as a hypothesis to explain and as a maxim to guide investment behavior. Also considers the rule that the investor does (or should) consider expected return desirable and variance of return undesirable. States this rule has many sound points, both as a maxim for and hypothesis about investment behavior. Illustrates geometrical relations between beliefs and choice of portfolio according to the "expected returns-variance of returns" rule. Shows that for a large, presumably representative range of expected returns and standard deviations, the "expected returns-variance of returns" rule leads to efficient portfolios almost all of which are diversified.

KEY WORDS: efficient portfolios, diversification theory, expected returns, variance of returns

27. Miller, Merton H.; Scholes, Myron. 1972. **Rates of return in relation to risk: a re-examination of some recent findings**. In: Jensen, Michael D., ed. Studies in the theory of capital markets. New York: Praeger Publishers: 47-78.

Re-examines earlier regression findings that say the mean annual rates of return on variances (and/or standard deviations) of annual rates for a large sample of common stocks for the period 1946-1963 "are consistent with the hypothesis that the market places a positive price on risk-bearing; for these distributions there is a significant relation between the means and a statistical risk proxy (standard deviation or variance)." Restates that where individual assets are concerned, the risk is defined (by extension) as the asset's contribution to the variance or risk of the portfolio as a whole. Finds that this risk generally will not be measured by the asset's "own variance" of return. Gives key propositions of modern portfolio theory and its assumptions and limitations. Concentrates on biases of the testing procedures that display enough *prima facie* sample evidence to warrant further, detailed investigation. States that many of these biases prevent earlier findings from being accepted into the canon of established empirical findings.

KEY WORDS: modern portfolio theory, risk

28. Robison, Lindon J.; Brake, John R. 1979. **Application of portfolio theory to farmer and lender behavior**. American Journal of Agricultural Economics. 61(1): 158-164.

Discusses developments in portfolio theory and reviews this theory's application to farmer and lender behavior. Considers the limitations of portfolio theory and suggests several extensions to account for asset liquidity, liquidity risk, and portfolio adjustments. Recommends future application of portfolio theory to farmer and lender behavior.

KEY WORDS: asset liquidity, liquidity risk, portfolio adjustments

29. Sharpe, William F. 1963. **A simplified model for portfolio analysis**. Management Science. 2: 277-293.

Describes the advantages of using the single-index model of the relationships among securities for practical applications of the Markowitz portfolio technique. Develops a computer program that can analyze 2,000 securities at an extremely low cost. Suggests that the few parameters used by the model can lead to almost the same results obtained with much larger sets of relationships among securities using quadratic programming.

KEY WORDS: single-index model, modern portfolio theory, computer program

30. Tsiang, S.C. 1972. **The rationale of the mean-standard deviation analysis, skewness preference, and the demand for money**. American Economic Review. 62: 354-371.

Points out that the mean-standard deviation analysis is justified for use beyond the case of quadratic utility functions or the case of normally distributed investment outcomes. However, states that the aggregate risk taken by the individual concerned must be small compared with their total wealth, including their physical, financial, and human wealth. Also points out that because of the constraint on the slopes of mean-standard deviation indifference curves, the mean-standard deviation analysis would not be capable of rationalizing the demand for idle cash in an investment portfolio. Justifies empirically the use of moments of distributions. Uses these moments of distributions for preference ordering of uncertain outcomes-aversion to dispersion, and for preference of skewness, when the slopes of mean-standard deviation indifference curves equal or exceed 45 degrees. Thinks mean-standard deviation analysis indicates that no investment demand for money can be made for the so-called portfolio balance purpose. States the demand for money must arise from the requirements of anticipated transactions and the precaution against contingencies calling for unplanned cash expenditures.

KEY WORDS: investment portfolio, risk, uncertainty

Stochastic Dominance

31. Bawa, Vijay S. 1975. **Optimal rules for ordering uncertain prospects**. Journal of Financial Economics. 2(1975): 95-121.

Obtains the optimal selection rule for ordering uncertain prospects for all individuals with decreasing absolute risk averse utility functions. Shows that the Third-Order Stochastic Dominance (TSD) rule is the optimal rule when comparing uncertain prospects with equal means. Studies the relationship of the optimal selection rule to others previously advocated in the literature, including the more popular mean-variance rule as well as the semi-variance rule.

KEY WORDS: third-order stochastic dominance, absolute risk averse utility functions

32. Bawa, Vijay S. 1982. **Stochastic dominance: a research bibliography**. Management Science. 28(6): 698-712.

Includes about 400 publications, working papers, and books on stochastic dominance in this bibliography. Contains an exhaustive list of papers that are either basic contributions to this subject or primarily concerned with applications of the stochastic dominance concepts. Also includes a selective listing of papers from finance, economics, mathematics, mathematical physics, mathematical psychology, operations research, and statistics literature to illustrate the wide acceptability of stochastic dominance.

KEY WORDS: stochastic dominance, decisions under uncertainty

33. Caulfield, Jon P. 1988. **A stochastic efficiency approach for determining the economic rotation of a forest stand**. Forest Science. 34(2): 441-457.

Employs stochastic dominance analysis to incorporate risk-aversion into the rotation decision. Demonstrates how to apply the technique in practice. Compares results with alternative decision rules, these being (1) deterministic land expectation value, (2) mean-variance rule, and (3) mean-coefficient of variation rule. Finds that results are consistent with previous work in that including risk identifies risk-efficient rotations that may be shorter than in the deterministic case. Identifies more than one risk-efficient rotation. Finds that the mean-variance rule cannot usefully be applied to the rotation decision and that the use of the mean-coefficient of variation rule defines a much larger efficient set than does stochastic dominance analysis. Shows that the degree of stochastic efficiency attained for a given rotation changes with annual probability of fire through a sensitivity analysis.

KEY WORDS: stochastic dominance, first-degree stochastic dominance, second-degree stochastic dominance

Forestry Investments

34. Anderson, Walter C.; Guldin, Richard W.; Vasievich, J. Michael. 1987. **Assessing the risk of insect attack in plantation investments**. Journal of Forestry. 85(1): 46-47.

Uses a method of forest-investment analysis developed by Hertz and Thomas (1983) that specifically includes risk. Begins the computer-backed process with the construction of a probability-density for each variable significantly affecting the investment outcome. Uses Monte Carlo simulation in the computer-based process. Plots risk profiles for low-attack thinned stands, high-attack unthinned stands, and for the group of stands reflecting the remaining four combinations of attack-thinning regimes. States all stands have essentially the same risk of failure (3 percent) to earn at least a 9.5 percent return.

KEY WORDS: risk-return, portfolio, Monte Carlo simulation

35. Brennan, Michael J.; Schwartz, Eduardo S. 1985. **Evaluating natural resource investments**. Journal of Business. 58(2): 135-156.

States that the evaluation of mining and other natural resource projects is made particularly difficult by the high degree of uncertainty attached to output prices. Shows that the techniques of continuous time arbitrage and stochastic control theory may be used not only to value such projects but also to determine the optimal policies for developing, managing, and abandoning them. States the approach may be adapted outside the natural resource sector.

KEY WORDS: uncertainty, continuous time arbitrage, stochastic control theory

36. Chambers, Robert G. 1989. **Healthy demand, constrained supply boost timber potential**. Pension World. June 1989. 3 p.

Thinks that to grasp timberland's market dynamics, investors need to know some basics about wood characteristics, the price/value of trees at different stages of maturity, and end-use markets. Discusses hardwoods, softwoods, housing industry, pulp and paper production, and the chip-n-saw industry. Maintains that timber market dynamics argue for long-term price appreciation.

KEY WORDS: timberland investments

37. Clarke, Harry R.; Reed, William J. 1989. **The tree-cutting problem in a stochastic environment: the case of age-dependent growth**. Journal of Economic Dynamics and Control. 13: 569-595.

Derives harvest policies for growing biological assets (*e.g.*, forests, livestock) subject to stochastic age-dependent growth and price uncertainty. Analyzes the task posed as a continuous-time optimal stopping problem for diffusion processes. Considers both "single" and "ongoing" rotations. Provides qualitative comparative static and numerical results.

KEY WORDS: harvest policies, price uncertainty

38. Conroy, Robert; Miles, Mike. 1989. **Commercial forestland in the pension portfolio: the biological beta**. Financial Analysts Journal. September-October: 46-54.

States that commercial forestland in the United States is unique enough in terms of risk/return value and large enough in terms of aggregate value to be considered for inclusion as a distinct asset class in the pension asset allocation process. Generates a return series under the assumptions that a timber portfolio consisted of N acres with each acre having timber of different ages and timber being cut at age N. Shows that harvest strategies of 23 years and up dominate when considering monthly returns and standard deviations of return for harvest strategies of from 10 to 41 years. Exposes a 10- to 11-year window of potential harvest and investment growth both in volume and quality. Uses a second return series that reflects the results of selling during this window only when prices are 5 percent above the rolling 12-month trend line for timber prices. Produces higher returns and lower variance than the first return series.

KEY WORDS: returns, pension asset allocation process

39. Dowdle, Barney. 1962. **Investment theory and forest management planning**. Bull. 67. New Haven, CT: Yale University, School of Forestry. 63 p.

Evaluates an approach to forestry investment analysis in which economic uncertainty and other sources of variation that might be associated with expected returns from investments could be explicitly set forth. Provides an empirical example of the expected returns-variance of returns rule. Estimates expected returns and variation of returns and applies these to the problem of determining cutting age for eastern white pine timber. Evaluates the theoretical objective of profit maximization. Defines and discusses what is relevant and how much relevant information is needed to analyze forestry investment opportunities. Provides an overview on the use of conversion-return calculations as a means of implementing forestry investment theory. Offers some general reflections on the overall problem of evaluating forestry investment alternatives.

KEY WORDS: expected returns-variance of returns rule, forestry investment, stumpage price estimations

40. Duerr, William A. 1989. **Pulsations in the forest industry**. Forest Products Journal. 39(9): 64-68.

Identifies the principal pulsations in forestry and the forest industry to recognize their social and physical context and to see how they serve to improve our understanding of the world and our foresight into its behavior. States that at least six kinds of pulsation in the economy affect forest-related activity, including cycles in stockholding firms' inventories, general business cycles, building cycles, inter-war cycles, Kondratrieff cycles, and forest-conservation cycles. Holds that the current position amidst these cycles is, by and large, promising for the future of the forest industry.

KEY WORDS: security measure, predictability

41. Harris, Thomas, Jr.; DeForest, Christopher; Futch, Scott; Cubbage, Frederick. 1989. **A survey of pension fund investments in timberland**. Southern Journal of Applied Forestry. 13(4): 188-192.

Cites a November 1987 survey of 1,500 pension and other tax-exempt funds found that 22 funds held an estimated $222 million of timberland; another 458 nonowners responded to the questionnaire. Reports that current investors plan to hold timberland for an average of 10 to 15 years, will maintain or increase their investment levels, and are moderately knowledgeable about and interested in timberland investments. Shows that noninvestors are much less knowledgeable and interested in timberland, but a few responding noninvestors felt that now is the appropriate time to invest in timberland.

KEY WORDS: questionnaire, investment levels

42. Hotvedt, James E.; Tedder, Philip L. 1978. **Systematic and unsystematic risk of rates of return associated with selected forest products companies**. Southern Journal of Agricultural Economics. 10(July): [135-138].

Measures total, systematic, and unsystematic risk of the rates of return for several forest products firms including Crown Zellerbach, Potlatch, International Paper, Westvaco, and Weyerhaeuser. Finds that the returns of four companies closely follow changes in the overall market. Compares the systematic risk associated with stocks of hundreds of other companies listed on the NYSE to the five forest products firms. Discusses the validity of results in risk analysis when single assets are analyzed rather than a portfolio.

KEY WORDS: total risk, single asset analysis

43. Howard, Theodore E.; Lacy, Susan E. 1986. **Forestry limited partnerships**. Journal of Forestry. 84(12): 39-43.

Determines the current status of forest-based limited partnerships by interviewing general and limited partners, investment advisors, and consulting foresters throughout the United States. Finds that the major forestry limited partnerships, together with a significant portion of the minor ones, total nearly 60 companies and represent more than 1 million acres of forest land. Suggests that intensified forest management may be required because investors expect competitive returns from their timberland investments as well

as capital security. States that growth in forestry limited partnerships will necessarily increase absentee ownership.

KEY WORDS: forestry limited partnerships, forest management, absentee ownership

44. Lacy, Susan E. 1989. **A risk-return analysis of timberland for the institutional investor**. Durham, NH: University of New Hampshire. 106 p. M.S. thesis.

Attempts to show that adding a timberland investment to an institutional portfolio may reduce risk and increase returns. Uses a harvest scheduling simulation model to calculate returns on a hypothetical southern pine plantation using actual stumpage prices from 1973 through 1982. Uses returns from the timberland investment and selected financial alternatives to statistically measure correlation and risk. Finds timberland returns were similar to selected financial alternatives during the 10-year investment horizon. Indicates that little correlation was found between timberland and financial investments. Through beta analysis of the returns, shows that timberland has lower risk when compared to the stock market.

KEY WORDS: timberland investment, southern pine

45. Luppold, William G. 1984. **An econometric study of the U.S. hardwood lumber market**. Forest Science. 30(4): 1027-1038.

Uses a recursive econometric model with the causal flow originating from demand relationship to analyze this market. Finds that market growth has been hindered by the availability of lower cost substitute materials and the economic uncertainty caused by the recursive aspects of the market. Links the nominal hardwood lumber price growth to the general level of national economic activity and general rate of inflation by way of the effect that the macroeconomy exerts on consumer goods prices and wage rates.

KEY WORDS: recursive econometric model

46. Mills, Walter L., Jr. 1988. **Forestland: investment attributes and diversification potential**. Journal of Forestry. 86(1): 19-24.

Gives advantages and disadvantages of forest land investments compared to other types of assets. Proposes a strategy to combine forest land investments with other investments to increase the positive and reduce the negative attributes of such combined investments.

KEY WORDS: real assets

47. Mills, W.L.; Hoover, William L. 1982. **Investment in forest land: aspects of risk and diversification**. Land Economics. 58(1): 33-51.

Explains portfolio analysis and diversification theory. Develops an investment decision model to determine if a plausible rationale exists for investing in forest land, given historical low net present values or internal rates of return. Demonstrates the possible usefulness of this approach through a case study including combinations of 4 financial investments, 4 Indiana farm options, and 10 Indiana central hardwood investments.

KEY WORDS: portfolio analysis, diversification theory

48. Redmond, Clair H.; Cubbage, Frederick W.; Harris, Thomas G., Jr. 1987. **Relationships among capital budgeting practices, timberland ownership and corporate performance in U.S. forest products firms**. Resource Management and Optimization. 6(1): 59-74.

Examines the relationships between the level of sophistication in capital budgeting techniques employed and corporate performances. Scored firms according to their use of modern capital budgeting techniques recommended in financial literature. Measures firm performance according to various market criteria. Indicates there were no detectable statistical relationships between capital budgeting practices and corporate performance of smaller firms. Finds that larger firms exhibited modest inverse relationships between capital budgeting sophistication and corporate performance. Indicates that timberland ownership also exhibited a small inverse association with performance.

KEY WORDS: performance measures

49. Rinehart, James A. 1985. **Institutional investment in U.S. timberlands**. Forest Products Journal. 35(5): 13-18.

Examines the cost of capital associated with the divestiture of industrial forest land and the returns to forest land ownership for large institutional, nonindustrial investors. Discusses the type of investors who may be interested in timberland ownership, their investment constraints, and institutional arrangements that can satisfy these constraints. Considers the recent and projected behavior of institutional forest land investors. Finds that divestiture of timberland is a likely source of capital for timber companies and that long-term investment in forest land can meet institutional needs. Indicates a propensity toward separating timber processing from timberland ownership and management.

KEY WORDS: cost of capital, timberland ownership

50. Rinehart, James A.; Saint-Pierre, Paul S. 1989. **Timberland: an industry, investment, and business overview**. Boston, MA: John Hancock Mutual Life Insurance Co. 85 p. Available from: The Hancock Timber Resource Group, Boston, MA.

Focuses on the fundamental value attributes of timberland investments with some educational perspective on the unique investment and operational elements of timberland assets. Presents both a historical perspective and an outlook on the future of investment and economic matters pertaining to timberland. Includes topics such as investment characteristics; investment process; timber industry economics; timberland management; CAPM; and demand, supply, and price trends.

KEY WORDS: forest, timber economics, price trends

51. Shearer, Michael T.; Ebner, Thomas J.; Webb, James F., Jr. 1987. **Risks associated with timberland investments and the timing of the investment to minimize the risk**. In: A clear look at timberland investment: options for the potential investor and current owner. Paper presented by James F. Webb, Jr., of First Wachovia Bank and Trust at the Forest Products Research Society conference; 1987 April 27-29; Milwaukee, WI.

Discusses the various types of risks associated with timberland investments. Examines many of the perceptions and fears of the investor, including both biological and financial risks. States that each risk factor within these categories can be managed or reduced in the woods, in the marketplace, or in a combination of both. Thinks timberland can reduce the overall risk of the investor's portfolio by combining this risk management capability with the fact that timber tends to be countercyclical with most traditional investments.

KEY WORDS: timberland investors, risk management

52. Stolz, Richard F. 1989. **Sponsors eye timberland investments**. Pension Fund News. May/June 1989. [Pages unknown].

States that pension funds willing to make a commitment to timber investments are drawn by promises of competitive returns, low volatility, and diversification. Suggests that pensions with existing investments in commercial real estate funds would be amenable to timberland investments because they can accept illiquidity. Reports from numerous timberland portfolio managers indicate that interest is increasing in timberland from pension funds.

KEY WORDS: pension funds, timberland portfolio

53. Teeguarden, Dennis E. 1969. **Economic criteria and calculated risk in reforestation investment decisions**. Journal of Forestry. 67(1): 25-31.

Reviews the use of economic criteria in making reforestation investment decisions. States that because of major long-term uncertainties, economic criteria define the problem but provide little help to land managers who wish to test the economic desirability of reforestation investments. Also states that benefit cost ratios may provide useful guides to efficient allocation of a fixed reforestation budget. Demonstrates an application of alternative rules for decisionmaking when outcomes are uncertain. Recommends the expected value rule for large-scale reforestation programs.

KEY WORDS: reforestation, investment decisions, uncertainty, expected value rule

54. Thomson, Thomas A. 1987. **Financial risk and timber portfolios for some southern and midwestern species**. In: Busby, Rodney L.; de Steiguer, J. Edward; Kurtz, William B., eds. The Blue and The Gray: 1987 joint meeting of the Southern Forest Economics Workers and the Midwest Forest Economists; 1987 April 8-10; Asheville, NC. Raleigh, NC: North Carolina State University: 46-55.

Uses finance techniques to assess the financial risk of growing commercial timber crops of saw logs in the Midwest and the South. Finds that the beta for growing each species is not statistically significant at the 95-percent level of significance, implying that the risk-free rate is the appropriate risk-adjusted discount rate to use in evaluating the timber growing opportunities in the Midwest and the South. Presents the minimum risk (for a desired rate of return) portfolio for timber growing in the South and the Midwest. Also presents portfolios that combine investing in the market and timber investments. Finds that a higher rate of return can be earned for any level of risk by investing in southern timber portfolios. Shows that a rational investor would invest in both regions, though most of the portfolio would be invested in southern species.

KEY WORDS: financial risk, portfolio analysis, timber

55. Thomson, Thomas A. 1989. **Evaluating some financial uncertainties of tree improvement using the capital asset pricing model and dominance analysis**. Canadian Journal of Forest Research. 19(11): 1380-1388.

Examines some financial uncertainties of a west coast Douglas-fir tree improvement program. Assumes *a priori* that biophysical uncertainties are nonmarket; thus, allowing for the use of expected value adjusts for these risks. Finds that the market uncertainties of tree improvement are reasonable, *vis-a-vis* other investments because sensitivity analysis shows that the financial risks were small, or the measured beta was low. Concludes that the tree improvement investment is worthwhile, considering its risk as well as return.

KEY WORDS: forestry investments, Douglas-fir

56. Thomson, Thomas A.; Baumgartner, David C. 1988. **Alternative specifications and solutions of the timber management portfolio problem**. In: Kent, Brian M.; Davis, Larry S., tech. coords. Systems analysis in forest resources: proceedings of a symposium; 1988 March 29-April 1; Pacific Grove, CA. Gen. Tech. Rep. RM-161. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 123-130.

Uses annual timber management returns for selected midwestern and southern species to compare the following methods of solving timber management portfolios: (1) quadratic programming, (2) classical optimization, (3) MOTAD, (4) Sharpe's single-index model, (5) stochastic dominance, and (6) growth optimal portfolios. Assumes that the timber species is managed in a fully regulated condition for producing sawtimber for each alternative. Finds that quadratic programming and MOTAD were the best options. Appears that classical optimization is not well suited for timber portfolios because negative portfolio weights are common; however, all the other techniques performed reasonably well. Finds that all of the portfolios were second-degree stochastically efficient; thus, the standard mean-variance appears to yield stochastically efficient results. Also finds that expected long-run returns are lower than expected single-period returns and that maximizing expected single-period return does not maximize long-run return.

KEY WORDS: timber management portfolio, second-degree stochastically efficient, quadratic programming, MOTAD, single-index model

57. Washburn, Courtland L.; Binkley, Clark S. 1989. **Is timber a good hedge against inflation?** In: Economic evaluation of timberland investments; Working Papers, 2d ed; 1989 June 1; New Haven, CT: Yale University, School of Forestry and Environmental Studies. 5 p.

Defines timberland as typically including some trees ready for harvest, some immature timber, and the land on which the trees stand. Finds that investing in timber is a good way to hedge against inflation in the short run. States that the decision to hold a position in timber must rest on the longer term returns associated with forest growth and real price increases and on the extraordinarily low financial risk associated with investments in U.S. timberland. Uses southern pine data to show findings.

KEY WORDS: risk-return, southern pine

58. Washburn, Courtland L.; Binkley, Clark S. 1990. **Informational efficiency of markets for stumpage**. American Agricultural Economics Association. 7(3): 394-405.

Examines the weak form efficiency of markets for pine sawtimber stumpage in the southern U.S. Indicates that stumpage markets are efficient from analyses of annual and quarterly rates of price change. Finds that stumpage markets do not pass the tests for weak-form efficiency when viewed at monthly intervals. Attributes this failure to friction in the market due to the time and cost involved in consummating timber sales. States the results have implications for price-responsive timber harvest scheduling, for application of asset pricing models to forestry investments, and for policies governing sales of timber from public land.

KEY WORDS: weak-form efficiency, stumpage prices, southern pine, forestry investments

59. Washburn, Courtland L.; Binkley, Clark S. [In press]. **On the use of period-average stumpage prices to estimate forest asset pricing models**. Land Economics. 66(4): 379-393.

Discusses the disparity between the reporting of stumpage prices and the prices of financial assets. Confounds the definition of comparable periods for measuring forest and market returns. Shows that the choice of comparable period has substantive and systematic consequences for the estimates of model parameters. Examines three alternative estimation techniques designed to resolve the confusion and produce more accurate parameter estimates.

KEY WORDS: market returns, model parameters

60. Zinkhan, F. Christian. 1988a. **Evaluating the performance of a forest products firm**. Forest Products Journal. 38(9): 33-36.

States that financial ratios are conceptually imperfect indicators of the overall financial performance of publicly held forest products firms because they (1) are based on accounting data, (2) ignore risk, and (3) discourage long-term planning horizons. Addresses this problem by looking at a market value, risk-adjusted approach for evaluating financial performances. Finds that output is significantly correlated with return on equity results for a group of forest products firms. Also finds that the financial performance ranking of a large portion of forest products firms depends greatly upon the performance indicator used. Recommends the market value, risk-adjusted approach as an indicator of overall financial performance.

KEY WORDS: financial performance, forest products firms

61. Zinkhan, F. Christian. 1988b. **Forestry projects, modern portfolio theory, and discount rate selection**. Southern Journal of Applied Forestry. 12(2): 132-135.

Illustrates that timberland investments can offer substantial risk-reduction benefits for investors holding diversified portfolios. Finds that the current required rate of return on an investment in southern timberland is less than the rate on U.S. Treasury bills due to a negative beta from timberland investments. Presents an approach for selecting a discount rate for long-term forestry projects undertaken either by individuals with diversified portfolios or by corporations with shareholders owning diversified portfolios.

KEY WORDS: timberland investments, discount rate, diversified portfolio

62. Zinkhan, F. Christian. 1988c. **The stock market's reaction to timberland ownership and restructuring announcement: a note**. Forest Science. 34: 815-819.

States that four publicly traded forest products firms have distributed a total of 8 million acres of timberland to publicly offered limited partnerships. Finds that shareholders benefited significantly around the announcement date of the event. Suggests that the share prices of the forest products firms did not adequately reflect the value of their timberland prior to announcement.

KEY WORDS: forest products firms, timberland limited partnership, timberland spin-off

63. Zinkhan, F. Christian. 1988d. **The term structure of interest rates and the evaluation of forestry investments: a note**. Southern Journal of Applied Forestry. 12(4): 256-258.

Proposes the consideration of the term structure of interest rates when using the net present value criterion in conjunction with long-term forestry investments. Demonstrates the potential valuation impact of considering (versus not considering) the term structure of interest rates. Using an actual 10-year case analysis, finds that the valuation of a timberland tract differed by approximately 11 percent depending on whether or not the term structure of interest rates was recognized.

KEY WORDS: interest rates, net present value, discount rate

64. Zinkhan, F. Christian. 1989. **Timber analysis perplexing**. Pensions & Investment Age. 17(9): 47-48.

States that the lack of a recognized performance standard for timberland presents an obstacle for analyzing the appropriateness of the investment in a portfolio. States that one of timberland's biggest informational deficiencies is the lack of a generally accepted index. Gives suggestions for potential application of a widely used index that could be used for a market gauge, a model, and also for a benchmark. Addresses two other questions about the design of a timberland index: (1) should the index be based on a hypothetical timberland fund or the performance of a sample tract? and (2) should land value data be based on appraised values or prices from actual transactions?

KEY WORDS: timberland index

65. Zinkhan, F. Christian. 1990. **Timberland as an asset for institutional portfolios**. Real Estate Review. 19(4): 69-74.

States that those institutional investors whose portfolios include timberland usually consider timberland to be a subset of the real estate portfolio rather than a separate investment category. Gives an overview of timberland investments. Measures the diversification benefits of adding forest land to the portfolio. Discusses the correlations of real returns and efficient frontiers for three portfolio categories. Attains, at high risk levels, a notable improvement in risk-return efficiency when southern pine timberland is added to the following list of portfolio alternatives: a U.S. Treasury bill proxy, a U.S. Treasury bond proxy, a broad common stock proxy, a commercial real estate proxy, and a farmland proxy.

KEY WORDS: timberland investments, risk-return, southern pine

66. Zinkhan, F. Christian; Mitchell, Kossuth. 1990. **Timberland indexes and portfolio management**. Southern Journal of Applied Forestry. 14(3): 119-124.

Explores two applications for the Southern Timberland Index Fund (STIF): asset allocation and investment performance evaluation. Discovers that the mean risk of risk-return efficient portfolios containing financial assets and the STIF is 43 percent less than the mean risk of the efficient portfolios containing only financial assets for the asset allocation application. Finds that the efficient portfolios contain the STIF in proportions as high as almost 30 percent. Suggests that a timberland index can be used as a benchmark for evaluating (1) performance of timberland investment managers and (2) investment performance of timberland versus other investment alternatives. Recommends that problems associated with existing timberland indexes be addressed before such applications become commonplace.

KEY WORDS: asset allocation, investment performance evaluation, efficient portfolios

Decision Theory

67. Bentley, W.R.; Kaiser, H.F., Jr. 1967. **Sequential decisions in timber management—a Christmas tree case study**. Journal of Forestry. 65(10): 714-719.

States that the relationship of production decisions, chance events, and value outcomes may be represented as a decision tree. Feels the decision-tree approach has applications to practical timber management problems. Illustrates the use of this technique for ranking alternative investment paths with a case study of Christmas tree production in Iowa. Integrates technical information, economic analysis, expert

opinion, and managerial judgment with the practical technique. Determines the importance of key decision factors, such as expected price and growth rate, through sensitivity analysis.

KEY WORDS: decision-tree approach, timber management

68. Best, M.J. 1975. **A feasible conjugate-direction method to solve linearly constrained minimization problems**. Journal of Optimization Theory and Applications. 16(1/2): 25-38.

Presents an interactive procedure that uses conjugate directions to minimize a nonlinear function subject to linear inequality constraints. Uses a method that (1) converges to a stationary point assuming only first-order differentiability; (2) has an n-q step superlinear or quadratic rate of convergence with stronger assumptions; (3) requires the computation of only the objective function and its first derivatives; and (4) is experimentally competitive with well-known methods, such as the revised reduced gradient method, the corrected gradient method, and the method of Klingman and Himmelblau.

KEY WORDS: mathematical programming, quadratically convergent algorithms, conjugate-direction methods, linearly constrained nonlinear programming, nonlinear programming

69. Binkley, Clark S. 1981. **Duration dependent discounting?** Canadian Journal of Forest Research. 11: 454-456.

Reviews literature on the choice of discount rate. Discusses why the variance of the rate of return might decline with the duration of the investment and presents empirical evidence that it does. Develops a model of investment decisions under uncertainty. Finds that it is not sufficient to simply adjust the discount rate for timber investments to reflect the maximum rate of return available for that duration. Suggests that the analyst must consider the probability distribution of returns from the timber investment and compare the expected return with that available in other competitive instruments.

KEY WORDS: discount rate, uncertainty, timber investments

70. Caulfield, Jon P.; Shoulders, Eugene; Lockaby, B. Graeme. 1988. **Methods for including risk in species-site selection decisions**. In: Proceedings, 5th Biennial Southern silvicultural research conference; 1988 November 1-3; Memphis, TN. Gen. Tech. Rep. SO-74. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 181-186.

Uses the mean-variance rule and stochastic dominance analysis to show how risk can be included in species-site selection decisions. Compares the volumes from 20-year-old plots of loblolly, slash, and longleaf pine on wet, intermediate, and dry sites. Concludes that longleaf pine is always outperformed by the other species and that slash outperforms loblolly on wet sites and tends to have higher volumes on dry sites.

KEY WORDS: mean-variance rule, stochastic dominance analysis, loblolly pine, longleaf pine

71. Cubbage, Frederick W.; Redmond, Clair H. 1985. **Capital budgeting practices in the forest products industry**. Forest Products Journal. 35(9): 55-60.

Surveys the major forest products firms regarding their capital budgeting procedures. Finds that the discounted cash flow measures are the preferred criteria for most investment decisions; internal rate of return was used most often, followed by net present value. States that forest products firms usually defined and evaluated risk in subjective nonquantitative terms. Finds that the weighted average cost of capital was used most often in determining the corporate discount rate that was usually applied to all project analysis decisions. States that investments in timberland used similar investment criteria but differed somewhat in the treatment of risk and use of discount rates.

KEY WORDS: internal rate of return, net present value, timberland investment, risk

72. Dane, C.W. 1965. **Statistical decision theory and its application to forest engineering**. Journal of Forestry. 63(4): 276-279.

Uses a hypothetical logging problem to demonstrate the application of statistical decision

theory and Bayesian statistics to a forest engineering problem. Feels that the decisionmaker does not have a "linear" attitude toward money in a risk situation; therefore, the "expected utility" decision rule would replace that of "expected value." Proposes that forest engineers may determine whether additional information is desirable by incorporating the Bayesian approach to probability with statistical decision theory.

KEY WORDS: statistical decision theory, Bayesian statistics, forest engineering

73. Field, David B. 1986. **Applications of statistical decision theory to the planning and control of forestry operations**. In: Proceedings, 18th IUFRO World Congress; 1986 September 9; Ljubljana, Yugoslavia. Ljubljana, Yugoslavia: Yugoslav IUFRO World Congress Organizing Committee. 16 p.

Offers a brief description of statistical decision theory, a review of the literature on applications of the methodology in forestry, and a few observations on diversification as a risk-averse strategy. Gives some preliminary results of recent research that focuses on elements of risk in forestry financial analysis.

KEY WORDS: forestry investments, risk

74. Fight, R.D.; Bell, E.F. 1977. **Coping with uncertainty—a conceptual approach for timber management planning**. Gen. Tech. Rep. PNW-59. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 18 p.

Gives an overview of various approaches to decisionmaking that explicitly recognize risk and uncertainty. Presents a framework for making a consistent set of timber management planning assumptions.

KEY WORDS: timber management planning, uncertainty

75. Flora, Donald F. 1964. **Uncertainty in forest investment decisions**. Journal of Forestry. 62(6): 376-379.

Proposes that uncertainty can be ignored if certain assumptions are plausible and if decisions are between forestry investments whose returns are about equally distant in time. Cites some analyses of forestry rates of return, unadjusted for uncertainty, as yardsticks for profitability.

KEY WORDS: forestry investments, rates of return, uncertainty

76. Fortson, James C. 1986. **Factors affecting the discount rate for forestry investments**. Forest Products Journal. 36(6): 67-72.

Reviews current capital budgeting techniques and demonstrates the superiority of the net present value criterion. Includes a historical review of procedures to objectively quantify risk for firms whose stock is widely traded. Develops procedures to objectively quantify risk; examples in forest investments are presented and explained. Based the outlined procedures on the assumption of perfect capital markets. States many of the procedures are most useful for firms whose stock is widely traded; therefore, they will be of limited value for public agencies.

KEY WORDS: capital budgeting techniques, net present value criterion, forestry investments

77. Fortson, James C.; Field, Richard C. 1979. **Capital budgeting techniques for forestry: a review**. Southern Journal of Applied Forestry. 3(4): 141-143.

Presents the key steps in the financial analysis of proposed capital expenditures. Gives the conditions under which the net present value or internal rate of return is the appropriate decision criterion. Reviews the factors that affect the choice of the discounting interest rate for cash flows.

KEY WORDS: net present value, internal rate of return, decision criteria

78. Hazell, P.B.R. 1971. **A linear alternative to quadratic and semivariance programming for farm planning under uncertainty**. American Journal of Agricultural Economics. 53(1971): 53-62.

States that quadratic decision criteria for farm planning are theoretically appealing but difficult to handle computationally at this time. Reviews the advantages of the quadratic approach for farm planning. Develops a linear alternative that, while retaining most of the desired features of the quadratic models, can be readily solved on conventional linear programming codes with the parametric option. Refers to this model as the Minimization of Total Absolute Deviation (MOTAD). Justifies empirically the proposed MOTAD

model for the E-mean absolute income deviation criterion as an approximate computational procedure for deriving efficient mean-variance form plans. States MOTAD is an alternative when a good quadratic program is not available.

KEY WORDS: quadratic decision criteria, linear programming, MOTAD

79. Johnson, S.R. 1967. **A re-examination of the farm diversification problem**. Journal of Farm Economics. 49(1967): 610-621.

States that when net incomes from farm enterprises are viewed in probabilistic terms and the farmer is assumed to be endowed with a particular amount of land, the problem of selecting an optimal mix of enterprises can be interpreted as a special case of the portfolio problem. Applies the separation theorem and its immediate corollaries to the farm diversification problem under general conditions regarding both the decisionmaker's preference for risk and the feasible set determined by alternative mixes of enterprises. Suggests a number of extensions that improve the usefulness of the results.

KEY WORDS: separation theorem, risk preference

80. Kao, Chiang. 1982. **Optimal stocking levels and rotation under risk**. Forest Science. 28(4): 711-719.

Generalizes the usual joint optimization of stocking levels and rotation length discussed under the deterministic assumption to probabilistic cases. Constructs a probabilistic dynamic programming model. Presents an example for using the developed model to solve the optimal stocking levels and rotation problems for Douglas-fir. Finds that the effects of various degrees of indeterminateness, or risk in growth prediction, are that for larger variance of growth prediction, optimal regimes involve shorter rotations, lower stocking levels, and lower mean annual increments.

KEY WORDS: programming, deterministic model, probabilistic model, Douglas-fir

81. Kao, Chiang. 1984. **Optimal stocking levels and rotation under uncertainty**. Forest Science. 30(4): 921-927.

Uses information generated or previous stages to transform the decision problem from the case of uncertainty risk. Revises the growth function at each stage to include newly obtained growth data. Uses the current stocking level from the latest optimization as the initial stocking level for a new optimization. Calculates the mean annual increment (MAI) of each stage; the stage at which the MAI culminates is the optimal rotation. Applies this proposed model to a hypothetical Douglas-fir stand. Calculates the value of information from the MAI under certainty, risk, and uncertainty.

KEY WORDS: decision analysis, risk, dynamic programming, adaptive optimization, mean annual increment, Douglas-fir

82. Kaya, Ismail; Buongiorno, Joseph. 1987. **Economic harvesting of uneven-aged northern hardwood stands under risk: a Markovian decision model**. Forest Science. 33(4): 889-907.

Presents a method to determine economic harvesting policies for northern hardwood stands taking into account uncertain stand growth and prices. Uses a transition matrix giving the probability of a stand and market state in 5 years, given the current stand and market state. Gives the expected stand value, including land; the best management policy prescribes a specific harvest for each possible stand and market state. Does a sensitivity analysis of the effects of changes in discount rate, fixed costs, and transition probabilities on the best policy and the expected cutting cycle.

KEY WORDS: uncertainty, selection forest, Markov chains, simulation, management, cutting cycles

83. Lembersky, Mark R.; Johnson, K. Norman. 1975. **Optimal policies for managed stands: an infinite horizon Markov decision process approach**. Forest Science. 21(2): 109-122.

Presents an approach that optimizes investment in timber production (1) when the manager is faced with uncertainties both in future product markets and in the response of stands to management actions and (2) when the objective is to maximize total discounted expected returns for an unending time horizon. Formulates uncertainties in a Markovian decision process with the

state of each stand described by average tree size, stocking level, and market condition. Gives a "stationary" management policy in which the optimal action to apply to any stand depends only on the observed state and not on the decision time, past states, or past actions.

KEY WORDS: decisionmaking under uncertainty, probabilistic models, forest management, timber production

84. Mapp, H.P.; Helmers, G.A. 1984. **Methods of risk analysis for farm firms**. In: Barry, P.J., ed. Risk management in agriculture. Ames, IA: Iowa State University Press: 116-128.

Focuses on methods of risk analysis for farm firm research including quadratic risk programming, minimization of total absolute income deviation, and simulation analysis. Discusses advantages and disadvantages of each model. Reviews empirical studies that apply these methods to analyze the production, marketing, and financial alternatives of farmers under risky conditions. States no one model or approach to risk analysis is best at the firm level and that the appropriate model depends upon the specific problem, objectives of the research, data available, cost, and computational considerations.

KEY WORDS: quadratic programming, MOTAD, simulation analysis, solution reliability, sensitivity in risk analysis models

85. Marty, Robert. 1964. **Analyzing uncertain timber investments**. Res. Pap. NE-23. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 21 p.

Presents an analysis that makes use of multiple estimates of project profitability stemming from different assumptions about the true values of uncertain factors such as yields and prices. Screens competing projects to eliminate those that can be proved to be unprofitable, or surely less profitable than some other project regardless of the assumptions made about the values of certain factors. Identifies how much operative uncertainty exists. Discusses a few of the formal decision rules available to an investor.

KEY WORDS: uncertainty, project profitability, decision rules

86. Nelson, A. Gene; Harris, Tiffin D. 1978. **Designing an instructional package: the use of probabilities in farm decision making**. American Journal of Agricultural Economics. 60(5): 993-997.

Reviews the theory and methodology for incorporating probabilities into the decisionmaking process. Analyzes the audience and the specification of the instructional objectives. Determines the content for the teaching module. Discusses alternative teaching methods. Describes the characteristics of the final package and some preliminary observations regarding evaluation.

KEY WORDS: farm decisionmaking, probabilities, instructional package

87. Schurle, Bryan W.; Erven, Bernard L. 1979. **The trade-off between return and risk in farm enterprise choice**. North Central Journal of Agricultural Economics. 1(1): 15-21.

Uses a modified linear programming MOTAD to address an enterprise choice problem involving production of grain crops, processing of tomatoes, and/or processing of cucumbers. Found the MOTAD procedure useful for handling risk. States the efficiency frontiers and accompanying farm plans permit a farm decisionmaker to evaluate the tradeoffs between return and risk. Found that tomatoes and cucumbers substantially extend the range of return and risk possibilities relative to those with only corn, soybeans, and wheat in the model. States the diversification opportunities provided by the specialty crops reduce the overall risk associated with each level of return when only grain crops are included.

KEY WORDS: farm crops, decisionmaking, diversification

88. Schurle, Bryan; Erven, Bernard L. 1979. **Sensitivity of efficient frontiers developed for farm enterprise choice decisions**. American Journal of Agricultural Economics. 61(3): 506-511.

Reports on the sensitivity of efficient frontiers developed in a farm enterprise choice study. Addresses the question of how much change in risk accompanies an enterprise combination change when expected return is held constant. Uses a modified linear-programming alternative (MOTAD) model. Concludes from results that a basis exists for questioning the quality of decisions made using the efficient frontier.

KEY WORDS: farm enterprise choice decisions, MOTAD, efficient frontier

89. Sonka, S.T.; Patrick, G.F. 1984. **Risk management and decision making in agricultural firms.** In: Barry, P.J., ed. Risk management in agriculture. Ames, IA: Iowa State University Press: 95-115.

Considers several aspects of risk management in the farm firm. Contrasts alternative views of risk and evaluates their adequacy for decision-making. Identifies the typical sources of risk in agriculture and the risk responses available to and utilized by farm operators. Finds that a farmer's response to risk may be in production, marketing, or the financial organization of the farm business. Suggests that an integrated strategy should be used when dealing with multiple sources of risks. Also identifies two methods of eliciting subjective probabilities as a type of risk response.

KEY WORDS: farm management, farm decision-making

90. Thompson, Emmett F. 1968. **The theory of decision under uncertainty and possible applications in forest management.** Forest Science. 14(2): 156-163.

Investigates the compatibility of Bayesian decision theory and forest management decision-making problems under uncertainty. Gives examples of two possibilities for applying Bayesian decision theory in forest management.

KEY WORDS: forest management, Bayesian decision theory

91. Young, D.L. 1984. **Risk concepts and measures for decision analysis.** In: Barry, P.J., ed. Risk management in agriculture. Ames, IA: Iowa State University Press: 31-42.

Identifies risk concepts for three classes of decision rules: (1) those requiring no probability information, (2) safety-first rules, and (3) expected utility maximization rules. Finds that once the appropriate risk concept is identified, subjective probabilities elicited from decisionmakers are appropriate risk measures when predicting decisionmakers choices. Also finds that objective probabilities are appropriate when the analyst is identifying normative strategies for a stated decision rule. States that the normative decision models require information on the expected returns and risk of future actions; consequently, the expected returns parameter is viewed as a statistical forecast. Similarly, the statistical variance of the forecast is an appropriate measure of risk for normative decision models.

KEY WORDS: decision rules, risk concept, objective and subjective probabilities

Option Pricing

92. Black, Fischer; Scholes, Myron. 1973. **The pricing of options and corporate liabilities.** Journal of Political Economy. 3: 637-654.

States if options are correctly priced in the market, it should not be possible to make guaranteed profits by creating portfolios of long and short positions in options and their underlying stocks. Derives the famous Black-Scholes theoretical valuation formula (the option pricing model) using the preceding principle. States that because almost all corporate liabilities can be viewed as combinations of options, the formula and the analysis that led to it are also applicable to corporate liabilities. Finds that the formula can be used to derive the discount that should be applied to a corporate bond because of the possibility of default.

KEY WORDS: Black-Scholes option pricing model, stock market

93. Cox, John C.; Ross, Stephen A.; Rubinstein, Mark. 1979. **Option pricing: a simplified approach.** Journal of Financial Economics. 7: 229-263.

Presents a simple discrete-time model for valuing options known as the binomial option pricing model. Requires only elementary mathematics, yet it contains, as a special limiting case, the celebrated Black-Scholes model, which was previously derived only by much more difficult methods. States the model readily lends itself to generalization in many ways. States that by its very construction it gives rise to a simple and efficient numerical procedure for valuing options for which premature exercise may be optimal.

KEY WORDS: binomial option pricing model, risk, Black-Scholes option pricing model

94. Mason, S.P.; Merton, R.C. 1985. **The role of contingent claims analysis in corporate finance**. In: Altrian, E.I.; Subrahmanyam, M.G., eds. Recent advances in corporate finance. Homewood, IL: Richard D. Irwin: 9-54.

Defines contingent claims analysis (CCA) as a technique for determining the price of a security whose payoffs depend on the prices of one or more other securities. States the origins of CCA are found in the theory of option pricing. Reviews basic option analysis including the Black-Scholes option pricing model. Looks at corporate liabilities as options.

KEY WORDS: corporate liabilities, options, Black-Scholes option pricing model

95. Morck, Randall; Schwartz, Eduardo; Stangeland, David. 1989. **The valuation of forestry resources under stochastic prices and inventories**. Journal of Financial and Quantitative Analysis. 24(4): 473-487.

States a contingent claims approach to capital budgeting may be preferable to traditional methods where uncertainty and managers' strategic reactions to changing conditions are important. Solves the classical problem of the duration of an investment in forestry resource in the general case of stochastic output prices and stochastic natural growth rate and timber inventories. Uses a contingent claims approach to value the forestry resources as a function of: (1) stochastic prices and inventories; and (2) an asymmetric, optimal production policy that incorporates the option to halt timber production temporarily.

KEY WORDS: contingent claims, timber production

96. Rubinstein, Mark. 1987. **Derivative assets analysis**. Economic Perspectives. 1(2): 73-93.

Discusses the analysis of derivative assets including those based on buy-and-hold strategies and on dynamic replicating strategies. Looks at the valuing and replicating of other derivative assets. Discusses the Black-Scholes model and how only two traded assets (one riskless) are needed to manufacture any derivative asset whose payoff is a deterministic function of the terminal value of the underlying asset price. Gives a detailed look at four applications of derivative assets analysis: index futures, equity options, index options, and portfolio insurance.

KEY WORDS: derivative assets, Black-Scholes option pricing model

97. Varian, Hal R. 1987. **The arbitrage principle in financial economics**. Economic Perspectives. 1(2): 55-72.

Shows how the principle of arbitrage can be used to calculate the necessary equilibrium relations between the values of assets in financial markets. Examines the concept of the absence of arbitrage. Looks at several applications of the no arbitrage condition in the theory of option pricing. Discusses the relationship between option values and state prices. Looks at pure security prices for dynamic stochastic processes.

KEY WORDS: arbitrage, no arbitrage conditions, option pricing theory, pure security prices

98. Zinkhan, F. Christian. 1990. **Option pricing, the land use conversion option, and timberland valuation**. In: 26th Annual meeting of the Eastern Finance Association; 1990 April 4-7; Charleston, SC. 20 p.

Uses option pricing methodology to value the owner's right to convert land from timber growing to some alternative land use. Revises the Black-Scholes option pricing model to incorporate approaches for valuing the land use conversion option and associated timberland tract. Reveals, through sensitivity analysis, that estimates from this new timberland valuation methodology for a hypothetical southern pine tract are generally less sensitive to financial and managerial inputs than the output from a traditional discounted cash flow approach. Encourages future researchers to focus on empirical testing of an option pricing-based timberland valuation model.

KEY WORDS: Black-Scholes option pricing model, land use, contingent claims

Stock Market

99. Chen, Nai-Fu; Roll, Richard; Ross, Stephen A. 1986. **Economic forces in the stock market**. Journal of Business. 59(3): 383-403.

Tests whether innovations in macroeconomic variables are risks that are rewarded in the stock market. Suggests that the following macroeconomics variables from financial theory should systematically affect stock market returns: the spread between long and short interest rates, expected and unexpected inflation, industrial production, and the spread between high- and low-grade bonds. Finds that these sources of risk are significantly priced. States that neither the market portfolio nor aggregate consumption is priced separately. Finds that all price risk is not separately rewarded in the stock market.

KEY WORDS: risk, stock market returns, macroeconomic variables

100. Douglas, George W. 1969. **Risk in the equity markets: an empirical appraisal of market efficiency**. Yale Economic Essays. 9(Spring): 3-45.

Conducts an empirical study to test in various ways the consistency and rationality of equity markets. States that the equity markets have a role in allocating risky assets among predominantly risk-averse investors. Efficiency in performing this function depends on the ability of participants to perceive and distinguish (*ex ante*) the characteristics of the returns distributions of the various assets. Presents empirical results indicating that the market priced individual assets with respect to their own risk in the way anticipated. States a higher order of efficiency can be achieved if information on the covariance of returns among assets is available and is used to assemble efficient portfolios. Finds that professional portfolio managers were not successfully exploiting covariance information, and that they do not seem to have better perception of expected returns than "the market." Also, investigates the behavior of the equity markets in generating capital risk (price volatility).

KEY WORDS: equity markets, market efficiency

101. Elton, Edwin J.; Gruber, Martin J. 1973. **Estimating the dependence structure of share prices—implications for portfolio selection**. Journal of Finance. 27(5): 1203-1232.

Estimates the correlation matrix of stock returns from historical data. Compares estimates both with respect to their ability to forecast correlation matrices and with respect to choose portfolios that prove to be efficient in future periods. Discusses the general types of forecasting models that could be used, their characteristics, and the variant of each model tested. Presents empirical results.

KEY WORDS: forecasting models, stock returns

102. Ibbotson, R.G.; Sinquefield, R.A. 1989. **Stocks, bonds, bills, and inflation: historical returns (1926-1987)**. Charlottesville, VA: University of Virginia, The Research Foundation of the Institute of Chartered Financial Analysts. 202 p.

Gives a history of the returns of the capital markets in the United States from 1926 to 1987. Provides data and a "thinking person's guide" to using historical data to understand financial markets and the decision process.

KEY WORDS: data, decision process, financial analysis

103. Roll, Richard; Ross, Stephen A. 1984. **The arbitrage pricing theory approach to strategic portfolio planning**. Financial Analysts Journal. 40(3): 14-26.

Provides an intuitive description of the arbitrage pricing theory (APT) and discusses its merits for managing portfolios. States the APT approach to the portfolio strategy decision involves choosing the desirable degree of exposure to the fundamental economic risks that influence both asset returns and organizations. Describes systematic factors and their influence on portfolio returns. Defines sensitivities as the responses of asset return to unanticipated movements in economic factors. Suggests a method for choosing the proper mix of assets for a given portfolio strategy. Relates the arbitrage pricing theory to CAPM. Gives suggestions for analyzing and implementing the strategy.

KEY WORDS: CAPM, risk exposure, portfolio strategy

Computer Applications

104. Arvanitus, Loukas G.; O'Regan, William G. 1967. **Computer simulation and economic efficiency in forest sampling**. Hilgardia. 38(2): 133-164.

Uses simulation techniques to obtain variance functions for various parameters and forests. Devises cost functions for each estimator; discovers economically efficient sampling plans. Finds that on the basis of the cost of measuring a number of trees as a point, and for the forest studied, a better estimate for number of trees, ingrowth, and growth in basal area is obtained from circular plots than from point sampling but that point sampling yields a better estimate of basal area. Also finds that on the basis of optimum combinations of variance and cost functions, plots are better than points for estimating number of trees, ingrowth, and basal area growth, while points are superior for estimating basal area. Suggests avoiding generalizations concerning sampling optimums for various forest parameters unless enough evidence is available to justify them.

KEY WORDS: forestry sampling, cost functions, variance

105. Chambers, Paul C.; Sinclair, Steven A.; Hassler, Curt C.; Hansen, Bruce G. 1986. **Forest products investment model: a microcomputer tool for incorporating risk into capital budgeting**. Forest Products Journal. 36(1): 64-68.

Describes the forest products investment model that evaluates and compares investment alternatives. Enables users to assess the consequences of risky future cash flows as one part of their investment analysis process. Provides the decisionmaker with the probability of achieving a certain net present value. Includes a histogram in the program output that displays the distribution of net present values. Gives the mean, standard deviation, and probability of having a positive net present value.

KEY WORDS: computer program - the Forest Products Investment Model, investment analysis process, net present value

106. Engelhard, Robert J.; Anderson, Walter C. 1983. **A method of assessing risk in forestry investments**. Res. Pap. SO-189. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 13 p.

Discusses, in detail, the Hertz method, which is a computer-based capital investment risk analysis procedure involving Monte Carlo simulation. Hypothesizes an investment in a slash pine plantation to demonstrate the Hertz method. Includes flowchart and FORTRAN computer code.

KEY WORDS: uncertainty, Monte Carlo simulation, probability distribution curve

107. Hepp, Todd E. **Analysis of risk in forestry investments**. 1989. The Compiler. 7(3): 46-49.

Discusses the risks associated with timber production as an investment. Uses the computer program YIELDplus to consider the most reasonable optimistic, pessimistic, and realistic scenarios for an example forest management policy.

KEY WORDS: computer program—YIELDplus, forest management, policy

108. Hof, John G.; Pickens, James B. **Chance-constrained and chance-maximizing mathematical programs in renewable resource management**. Forest Science. [In press].

Discusses a broad range of approaches to optimizing natural resource allocation in the situation where amounts of available input(s) and/or amounts of desired output(s) are random. Reviews the classic approach to this class of problems, "change-constrained programming" and a new alternative "total probability change-constrained programming." Develops three "chance-maximizing" counterparts. Develops specific formulations for executing these approaches in natural resource management problems that explicitly include the cumulative probability density functions. Demonstrates solution procedures with a forestry case example and shows that the different approaches can yield substantially different results. Compares results from different solution procedures.

KEY WORDS: linear programming, nonlinear programming, risk, uncertainty, random right-hand side, stochastic models

109. Pickens, James B.; Hof, John G.; Kent, Brian M. **Use of chance-constrained programming to account for stochastic variation in the A-matrix of large-scale linear programs: a forestry application**. Annals of Operations Research. [In press].

Uses a Monte Carlo simulation approach to describe the distribution of total output when the individual production coefficients are random. Develops an iterative procedure for "chance-constraining" feasibility and demonstrates with this sort of random A-matrix. Requires an iterative approach because the mean and variance of total output are unknown functions of the random A-matrix coefficients and the level of output required. Formulates a case study model using data collected by the USDA Forest Service.

KEY WORDS: wildland allocation, stochastic production estimates, stochastic A-matrix, chance-constrained programming

110. Saigal, R. 1986. **QPROG**. Ann Arbor, MI: Sci Computing.

Is a mathematical programming software package. Includes four subroutines written in BASIC. Uses the MP2-QPROG subroutine to set up the quadratic program as a linear complementary pivoting routine to solve the problem. Gives an efficient portfolio for a chosen rate of return.

KEY WORDS: efficient portfolio, rate of return, computer program

Textbooks

111. Anderson, Jock R.; Dillon, John L.; Hardaker, J. Brian. 1977. **Agricultural decision analysis**. Ames, IA: Iowa State University Press. 344 p.

112. Brealey, Richard; Myers, Stewart. 1984. **Principles of corporate finance**. 2d ed. New York: McGraw-Hill. 847 p.

113. Chance, Don M. 1989. **An introduction to options and futures**. New York: Dryden Press. 560 p.

114. Chernoff, Herman; Moses, Lincoln E. 1959. **Elementary decision theory**. New York: John Wiley & Sons. 364 p.

115. Clutter, Jerome L.; Fortson, James C.; Pienaar, Leon V.; Brister, Graham H.; Bailey, Robert L. 1983. **Timber management: a quantitative approach**. New York: John Wiley & Sons. 333 p.

116. Draper, Norman; Smith, Harry. 1981. **Applied regression analysis**. 2d ed. New York: John Wiley & Sons. 709 p.

117. Dunn, Olive Jean; Clark, Virginia A. 1987. **Applied statistics: analysis of variance and regression**. 2d ed. New York: John Wiley & Sons. 445 p.

118. Elton, E.J.; Gruber, M.J. 1981. **Modern portfolio theory and investment analysis**. New York: John Wiley & Sons. 645 p.

119. Francis, Jack Clark; Archer, Stephen H. 1979. **Portfolio analysis**. 2d ed. Englewood Cliffs, NJ: Prentice Hall, Inc. 411 p.

120. Hull, John. 1989. **Options, futures, and other derivative securities**. Englewood Cliffs, NJ: Prentice Hall, Inc. 341 p.

121. Luce, R. Duncan; Faiffa, Howard. 1957. **Games and decisions—introduction and critical review: a study of the behavioral models project**. New York: John Wiley & Sons. 509 p.

122. Reilly, Frank K. 1986. **Investments**. 2d ed. Chicago: Dryden Press. 726 p.

123. Savage, Leonard J. 1954. **The foundations of statistics**. New York: John Wiley & Sons. 294 p.

124. Schlaifer, Robert. 1959. **Probability and statistics for business decisions; an introduction to managerial economics under uncertainty**. New York: McGraw-Hill. 732 p.

125. von Neumann, John. 1964. **Theory of games and economic behavior**. 3d ed. New York: Wiley. 641 p.

126. Wald, Abraham. 1971. **Statistical decision functions**. 2d ed. Bronx, NY: Chelsea Publ. Co. 179 p.

127. Weston, J. Fred; Copeland, Thomas E. 1986. **Managerial finance**. 8th ed. Chicago: Dryden Press. 1035 p.

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Contains a fairly complete set of references to the small but rapidly growing amount of literature directly related to the study of risk in forestry in the United States up to 1989. Also includes representative references for the huge literature of general financial theory dealing with risk. Includes 95 annotated references and 17 additional textbook references without annotations.

KEY WORDS: Risk, forestry investments, decision theory, asset pricing models

Our job at the North Central Forest Experiment Station is discovering and creating new knowledge and technology in the field of natural resources and conveying this information to the people who can use it. As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager meet these challenges while protecting the environment is what research at North Central is all about.